

REMARKS

This Preliminary Amendment cancels, without prejudice, claims 1-9 in the underlying PCT Application No. PCT/DE2004/000727 and adds new claims 10-18. The new claims, inter alia, conform the claims to United States Patent and Trademark Office rules and do not add any new matter to the application.

In accordance with 37 C.F.R. § 1.125(b), the Substitute Specification (including the Abstract) contains no new matter. The amendments reflected in the Substitute Specification (including Abstract) are to conform the Specification and Abstract to United States Patent and Trademark Office rules or to correct informalities. As required by 37 C.F.R. §§ 1.121(b)(3)(ii) and 1.125(c), a Marked-Up Version of the Substitute Specification comparing the Specification of record and the Substitute Specification also accompanies this Preliminary Amendment. Approval and entry of the Substitute Specification (including Abstract) are respectfully requested.

The underlying PCT Application No. PCT/DE2004/000727 includes an International Search Report, dated July 29, 2004, a copy of which is included. The Search Report includes a list of documents that were considered by the Examiner in the underlying PCT application.

It is respectfully submitted that the subject matter of the present application is new, non-obvious, and useful. Prompt consideration and allowance of the application are respectfully requested.

Respectfully Submitted,

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FUEL INJECTOR

Background Information FIELD OF THE INVENTION

The present invention is based on relates to a fuel injector of the type set forth in the main claim.

5 BACKGROUND INFORMATION

A fuel injector having a stepped spray-discharge orifice is known from described in German Patent Application No. DE 199 37 961 A1, for example. The spray-discharge orifice is divided into a through hole and a discharge-side or flow-off-side exit region, the exit 10 region differing from the through hole in form, contour and size.

A particular disadvantage of the fuel injector known from described in the aforementioned printed publication is that, given a correspondingly broadened fuel jet emerging from the through hole, 15 parts of the exit region may be directly exposed to the action of the fuel. In addition, in an exit region whose contour and size is similar to that of the fuel jet, no other volume remains in the exit region. As a result of both disadvantages, fuel remains in the vicinity of the discharge orifice after the spray-discharge 20 operation since hardly any gas turbulence, which removes fuel from the region of the spray-discharge orifice once the injection process has been completed, is able to form. This can cause combustion deposits to form after a short operating time, which have a disadvantageous effect on the further operation of the fuel 25 injector. In addition, the fuel residue that remains in the region of the spray-discharge orifice after the discharge operation increases the emission values and the fuel consumption.

Furthermore, it is impossible to fully adapt the length/width ratio and the fuel pressure to the various requirements of different internal combustion engines.

5 Summary of the Invention

SUMMARY

~~In contrast to the related art, the~~ An example fuel injector according to the present invention, ~~having the characterizing features of the main claim, has~~ may have the advantage of effectively preventing fuel deposits in the region of the spray-discharge orifice.

Moreover, the length/width ratio of the spray-discharge orifice and the fuel pressure may be freely modified and selected while retaining the gap size. The adaptation of the injection behavior of the fuel injector to different internal combustion engines may thus be carried out in an especially simple manner. The atomization, emission values and fuel consumption are improved.

~~Advantageous further developments of the fuel injector specified in the main claim are rendered possible by the measures elucidated in the dependent claims.~~

25 The In accordance with an example embodiment of the present invention, a remaining first volume is advantageously calculated according to the equation indicated in Claim 2, e.g.,
$$B = \frac{|D \cdot \pi \cdot A_g|}{|d \cdot \pi \cdot s|}$$
 and the gap dimension is not greater than 0.3 mm and not smaller than 0.1 mm since this ensures an optimally dimensioned first 30 volume even in the case of different geometries of the spray-discharge orifice or the exit region. An optimal vortex formation in the first volume is guaranteed, and an aspiration effect between the inner walls of the exit region and the fuel jet is reliably prevented.

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It is also advantageous that if the guide region and the exit region are arranged coaxially with respect to one another. This facilitates an especially uniform vortex formation in the first volume.

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Since the transition from guide region to exit region widens in a conical manner in the spray-discharge direction, the fuel jet is able to be guided in an advantageous fashion. The geometry of the fuel jet is thereby able to be adapted to the geometry of the 10 exit region.

Due to a cylindrical design of the exit region, the exit region is able to be produced in an especially simple manner.

15 If the guide region projects into the exit region and/or if the exit region at first widens continually counter to the spray-discharge direction, a vortex formation may be promoted as well.

20 ~~Brief Description of the Drawing~~

BRIEF DESCRIPTION OF THE DRAWINGS

Exemplary embodiments of the present invention are shown in a simplified version in the ~~drawings~~figures and ~~elucidated~~described 25 in greater detail in the ~~following~~descriptionbelow.

~~The figures show:~~

Fig. 1-A ~~shows~~ a schematic section through an example of a 30 ~~conventional~~ fuel injector ~~according to the related art,~~

Fig. 2-A ~~shows~~ a schematic section through a first exemplary embodiment of the fuel injector according to the present invention, in the region of the spray-discharge orifice, ~~and~~

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Fig. 3 shows a schematic section through a second exemplary embodiment of the fuel injector according to the present invention, in the region of the spray-discharge orifice.

5 ~~Description of the Exemplary Embodiments~~

DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS

In the following, exemplary embodiments of the present invention are described by way of example. Identical parts are provided with matching reference numerals in all of the figures. However, before 10 preferred exemplary embodiments of the present invention are elucidated in greater detail with the aid of Figures 2 and 3, for a better understanding of the present invention, a fuel injector 1 is briefly explained in its essentialbasic components on the basis of Figure 1.

15 A first exemplary embodiment of a fuel injector 1 according to the present invention, shown in Figure 1, is designed in the form of a fuel injector for fuel-injection systems of mixture-compressing internal combustion engines having externally supplied ignition. 20 Fuel injector 1 is particularly suited for the direct injection of fuel into a combustion chamber (not shown) of an internal combustion engine.

Fuel injector 1 is made up of a nozzle body 2 in which a valve needle 25 3 is positioned. Valve needle 3 is in operative connection with a valve-closure member 4, which cooperates with a valve-seat surface 6 positioned on a valve-seat body 5 to form a sealing seat. In the exemplary embodiment, fuel injector 1 is an inwardly opening 30 fuel injector 1, which has one spray-discharge orifice 7 which is produced by simple drilling, for instance. Seal 8 seals nozzle body 2 from an outer pole 9 of a solenoid coil 10. Solenoid coil 10 is encapsulated in a coil housing 11 and wound on a coil brace 12, which rests against an inner pole 13 of solenoid coil 10. Inner pole 13 and outer pole 9 are separated from one another by a

constriction 26 and interconnected by a non-ferromagnetic connecting part 29. Solenoid coil 10 is energized via a line 19 by an electric current, which may be supplied via an electrical plug contact 17. A plastic extrusion coat 18, which may be extruded 5 onto inner pole 13, encloses plug contact 17.

Valve needle 3 is guided in a valve-needle guide 14, which is in the form of a disk. A paired adjustment disk 15 is used to adjust the (valve) lift. An armature 20 is positioned on the other side 10 of adjustment disk 15. Via a first flange 21, it is connected to valve needle 3 by force-locking, and valve needle 3 is connected to first flange 21 by a welded seam 22. Braced on first flange 21 is a restoring spring 23, which is prestressed by a sleeve 24 in the present design of fuel injector 1.

15 Fuel channels 30, 31 and 32 run in valve-needle guide 14, armature 20 and along a guide element 36. The fuel is supplied via a central fuel supply 16 and filtered by a filter element 25. A seal 28 seals fuel injector 1 from a fuel distributor line (not shown further), 20 and an additional seal 37 seals it from a cylinder head (not shown further).

On the spray-discharge side of armature 20 is an annular damping 25 element 33 made of an elastomeric material. It rests on a second flange 34, which is integrally joined to valve needle 3 via a welded seam 35.

In the quiescent state of fuel injector 1, armature 20 is acted 30 upon by restoring spring 23 against its direction of lift, in such a way that valve-closure member 4 is held in sealing contact on valve-seat surface 6. In response to excitation of solenoid coil 10, it generates a magnetic field that moves armature 20 in the lift direction, counter to the spring force of restoring spring 23, the lift being predefined by a working gap 27 that occurs in

the rest position between inner pole 12 and armature 20. First flange 21, which is welded to valve needle 3, is taken along by armature 20, in the lift direction as well. Valve-closure member 4, which is connected to valve needle 3, lifts off from valve seat 5 surface 6, so that the fuel is spray-discharged through spray-discharge orifice 7.

In response to interruption of the coil current, following sufficient decay of the magnetic field, armature 20 falls away from 10 inner pole 13 due to the pressure of restoring spring 23, whereupon first flange 21, being connected to valve needle 3, moves in a direction counter to the lift. Valve needle 3 is thereby moved in the same direction, causing valve-closure member 4 to set down on valve seat surface 6 and fuel injector 1 to be closed.

15 Figure 2 shows a schematic section through a first exemplary embodiment of fuel injector 1 according to the present invention, in the region of spray-discharge orifice 7. Spray-discharge orifice 7 is made up of a guide region 38 which is arranged on the 20 inflow side, and an exit region 39 which is arranged on the spray-discharge side downstream from a transition 40 or a first step 41 thereto. Downstream from transition 40, rectangular step 41 widens guide region 38 into an exit region 39 extending in cylindrical form. In this exemplary embodiment, guide region 38 25 and exit region 39 are arranged coaxially with respect to one another.

In the exemplary embodiment, a fuel jet 42 emerging from guide 30 region 38 into exit region 39 or into the combustion chamber (not shown) is indicated by dashed lines. Upon exiting from guide region 38 and beginning with transition 40, fuel jet 42 widens conically at a jet angle 46. In the exemplary embodiment, fuel jet 42 exits from guide region 38 coaxially. The outer boundaries of fuel jet 42 emerge from exit region 39 at a discharge-side end 43 of exit

region 39 while maintaining a gap 44 having a gap dimension 47. Gap dimension 47 is greater than 0. Gap 44, having gap dimension 47, occurs at the shortest distance between fuel jet 42 and discharge-side end 43. Between transition 40 and gap 44, the outer 5 boundary of fuel jet 42 covers a distance s.

A first volume between gap 44, the outer boundaries of fuel jet 42 and the inner walls of exit region 39, is not acted upon by fuel jet 42 during the injection procedure in exit region 39. The 10 pressure is lowered in first volume 45 during the injection operation, which facilitates evaporation of the fuel. Gas vortexes are formed in volume 45, which contribute to the removal of fuel residue from spray-discharge orifice 7, in particular once the injection process has come to an end.

15 A longitudinal cross-sectional area A_g occurring in longitudinal section of first volume 45 has centers of mass 48 whose distance represents a first diameter D . The planar longitudinal section is implemented at a center axis (not shown) of exit region 39. A second 20 diameter d likewise occurs in such a longitudinal section between two points, which are located at the outer boundaries of fuel jet 42 at the midpoint of distance s .

25 In the exemplary embodiment illustrated, the gap dimension is between 0.1 mm and 0.3 mm, preferably 0.2 mm.

To produce an optimal turbulence formation in the first volume, a coefficient B , which characterizes the first volume, amounts to at least 0.5, but maximally 2.5, preferably 1.5 in the illustrated 30 exemplary embodiment.

Coefficient B is calculated according to the following formula:

$$B = \frac{|D \cdot \pi \cdot Ag|}{|d \cdot \pi \cdot s|}$$

All dimensioned variables are given in mm or mm².

5 Figure 3 shows a schematic section through a second exemplary embodiment of fuel injector 1 according to the present invention, in the region of spray-discharge orifice 7. This fuel injector functions in the same manner as the first exemplary embodiment of Figure 2, but has a two-piece design.

10 In contrast to the first exemplary embodiment of Figure 2, guide region 38 projects into exit region 39, and transition 40 widens conically in the spray-discharge direction. Furthermore, beginning with the discharge-side end of transition 40, exit region
15 39 at first runs counter to the discharge direction and then transitions into a cylindrical region, which continues to the discharge-side end 43 of exit region 39.

The present invention is not limited to the exemplary embodiments
20 shown and is also suitable, for instance, for outwardly opening fuel injectors 1 or multi-hole valves.

SummaryABSTRACT

A fuel injector-(1), in particular for the direct injection of fuel into a combustion chamber of an internal combustion engine, having 5 a valve-closure member-(4) which cooperates with a valve-seat surface-(6) formed on a valve-seat body-(5), to form a sealing seat, includes at least one spray-discharge orifice-(7) provided downstream from the sealing seat. The spray-discharge orifice-(7) has a guide region-(38) and an exit region-(39) arranged at its 10 discharge-side end. The exit region-(39) widens in a stepped manner by at least one first step-(41) and/or at least in part continuously beginning with a transition-(40) from the guide region-(38) into the exit region-(39). A fuel jet-(42) which emerges from the guide region-(38) at the transition-(40) and widens essentially uniformly 15 at a jet angle-(46), passes a discharge-side end-(43) of the exit region-(39) with a gap dimension-(47) of a gap-(44) after a distance s, the gap dimension-(47) being greater than zero and a first volume-(45) remaining in the exit region-(39) between the fuel jet-(42) and the inner walls of the exit region-(39).

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(Figure 2)